Chapter 7

Designing Research Studies

7.1 Introduction

In this chapter not only we will describe and compare what is an experiment and what is an observational study, but also we will learn how to deal with the problem of confounding variables in both cases. In an experiment, the *experimenter* decides who is to be given the treatment and who is to be the control. In an observational study, it is the *subject* who decides whether or not s/he is to be given the treatment. Generally speaking, whereas confounding variables are dealt with by *randomization* in experiments, confounding variables are dealt with by *blocking* for them in an observed study. Also, generally speaking, a replicated experiment or observed study, leading to more observations, is better than an experiment or observed study with fewer observations.

From a "big picture" point of view, we begin a detailed look at the statistical inference of (large n) multiple–sample mean problems.

		mean μ	variance σ^2	proportion π
	one	large n, 3.7, 3.8, 3.9, 3.10, 4.6 small n, 4.3, 4.6	4.4	6.2
sample	two	large n, 3.11 small n, 4.3	4.4	6.3
	multiple	**chapters** **7**, 8, 9	not done	6.2, 6.3

7.2 Some Useful Terminology

A new drug is introduced. How should an *experiment* be designed to test its effectiveness? The basic method is *comparison*. The drug is given to subjects in a *treatment group*, but others are used as *controls*–they aren't treated. Then the responses of the two groups are compared. Subjects should be assigned to treatment or to control *at random*, and the experiment should be run *double–blind*: neither the subjects nor the doctors who measure the responses should know who was in the treatment group and who was in the control group. *Freedman et al, 1991*

Exercise 7.1 (Experiments)

1. *Experiment, A First Look.* The effect of air temperature on the rate of oxygen consumption (ROC) of mice is investigated.

temperature	room temperature (70^o F)	10.3	14.0
	cold temperature (-10^o F)	9.7	11.2

   (a) **True** / **False** The ROC of one mouse at room temperature is 10.3 units.

   (b) How many mice *could* be used in this experiment? *Circle none, one or more.*

      i. Four: one mouse is subjected to room temperature, a second mouse is subjected to the same room temperature, a third mouse is subjected to the cold temperature and a fourth mouse is subjected to the same cold temperature.

      ii. Two: one mouse is subjected to both room temperature and the cold temperature and a second mouse is also subjected to both room temperature and the cold temperature.

      iii. One: one mouse is *twice* subjected to both room temperature and the cold temperature.

   (c) The *one* mouse design, described above, is probably (circle one) **better** / **worse** than the *four* mouse design in the sense we are sure the different ROCs are *not* being caused by different mice in the one mouse design and so, consequently, more certain the different ROCs are being caused by the different temperatures the mice are being subjected to.

   (d) **True** / **False** The *design* of the experiment, in other words, how we assign the different temperature levels to the different mice, is a *good* one, if, at the end of the experiment, we are very certain that it is the *temperature*, and *not* any other variable, that is influencing the ROC of mice.

   (e) The *two* mouse design, described above, is probably (circle one) **better** / **worse** than the *one* mouse design in the sense we are more certain that the *average* ROC of two *different* mice is more representative of the ROC of "typical" mice than the average ROC of one mouse measured twice.

(f) **True** / **False** The design of the experiment is a *good* one if the difference in average ROCs under the two different temperatures measured from the four ROCs of the *particular* mice used in the experiment is *representative* of the difference in the ROCs of *typical* mice. Representative results are more valuable to us because these results apply to not only to the few mice in the experiment, but also apply to all mice.

(g) The average ROC of the mice at *room* temperature is $\frac{10.3+14.0}{2} =$ (circle one) **10.45** / **11.45** / **11.95** / **12.15** / **12.65**.

(h) The average ROC of the mice at *cold* temperature is (circle one) **10.45** / **11.45** / **11.95** / **12.15** / **12.65**.

(i) The *difference* in the average ROC of the mice at room temperature and the average ROC of the mice at cold temperature is $12.15 - 10.45 =$ (circle one) **0.7** / **1.2** / **1.7** / **2.1** / **2.5**.

(j) The difference in the average ROC of the mice at room temperature and the average ROC of the mice at the cold temperature *could* be caused by (*circle none, one or more*)

   i. the different temperatures (we hope).
   ii. the different mice (unfortunately, if different mice are used).
   iii. the different lighting or noise conditions (unfortunately, if different lighting or noise conditions occur).
   iv. other unknown variables.

(k) We are *most* interested in determining the influence of (circle one) **temperature** / **mice** / **experimental conditions** / **unknown variables** on the ROC of the mice in this experiment.

(l) Each mouse is best described as an (circle one)
experimental unit / **response variable** / **observational unit**
of the experiment.
Each *pair* of mice subjected to one temperature level (room or cold) is best described as an (circle one)
experimental unit / **response variable** / **observational unit**
of the experiment.

(m) The four ROCs of the mice is best described as (circle one) **subjects** / **experimental units** / **responses** of the experiment.

(n) The *treatment variable* the mice are subjected to is (circle one) **temperature** / **10.3** / **ROC**.

(o) The two treatments are (circle one)

   i. room temperature and cold temperature
   ii. bright lighting and dark lighting

iii. 10.3 and 9.7

(p) The *status–quo* (or "do–nothing") treatment is often referred to as the *control treatment* or, more simply, as the *control*. In this case, the control is most likely the (circle one) **cold temperature** / **room temperature**.

(q) **True** / **False** Although it makes sense to designate room temperature as the control, it is possible to designate cold temperature as the control. The control, then, can actually be any one of the treatments.

(r) **True** / **False** The control *group*, in this case, are the two mice subjected to the control, the room temperature, say.

(s) It is necessary to have a control group because (circle none, one or more)

i. although we could measure the average ROC of the cold temperature group of mice, we would not know if this average ROC was high or low, unless we also had the average ROC of the room temperature group of mice (the control group, say) to compare against it.

ii. we are interested in determining the influence of temperature on the ROC of mice and without subjecting mice to at least two different temperatures, we would not be able to determine this influence.

iii. we need a group to *compare* against.

(t) If there are only two treatments in an experiment, one of the treatments is referred to as the control and the other is, confusingly, referred to as the "treatment". For example, if "room temperature" is the control, the "treatment", in this case, is the (circle one)

i. mice.

ii. ROC.

iii. room temperature.

iv. cold temperature.

2. *Another Experiment.* The effect of level of lighting on the heart pulse of deer mice is investigated. Four different mice are subjected to two lighting levels.

level of lighting	bright	10.3	14.0
	dim	9.7	11.2

(a) Match the descriptions in Column II with the statistical terms in Column I.

Column I	Column II
(a) treatment variable	**(a)** level of lighting
(b) control	**(b)** heart pulse
(c) response	**(c)** dim light
(d) experiment unit(s)	**(d)** deer mice
(e) observational unit(s)	**(e)** pair of deer mice subjected to same lighting

Column I	(a)	(b)	(c)	(d)	(e)
Column II					

(b) If the control is "dim lighting", the treatment is (circle one)

i. level of lighting

ii. bright lighting

Exercise 7.2 (Confounding, Experiments and Randomization)

1. *Confounding Variables: Air Temperature, Mice Weight and Rate of Oxygen Consumption.* Sixteen different mice are subjected to four different temperature levels to determine the effect of air temperature on the rate of oxygen consumption (ROC) of deer mice.

temperature	0^o F	3.4	4.1	2.1	3.1
	10^o F	7.4	8.7	8.2	7.9
	20^o F	9.3	10.3	11.4	9.7
	30^o F	12.4	16.1	18.1	19.1

(a) The treatment variable is (circle one) **ROC** / **temperature** / **deer mice**.

(b) There are (circle one) **1** / **2** / **3** / **4** treatment(s).

(c) Complete the following table of average ROCs of the mice subjected to the four temperatures:

temperature	0^o F	10^o F	20^o F	30^o F
average ROC	3.175	8.05		16.425

Hint: Average ROC at 20^o is calculated by adding 9.3, 10.3, 11.4 and 9.7 and dividing by four.

(d) It appears, looking at the table of average ROCs, that as the temperature *increases*, the average ROC (circle one) **increases** / **decreases**.

(e) It is discovered, later, after the experiment is complete, that, *un*intentionally, the mice subjected to the (0^o F, 10^o F, 20^o F, 30^o F) temperatures, were also found to be, respectively, (light, low–middle, high–middle, heavy) weight mice. In other words, as the weight of mouse *increases*, the average ROC (circle one) **increases** / **decreases**.

(f) As a consequence, (circle one)

i. it is clear that only temperature
ii. it is clear that only the weight of mouse
iii. it is not clear whether the weight of mouse or temperature or some combination of the two

influences the response variable, ROC of deer mice. Temperature is confounded with weight. However, since temperature is the variable of interest in this experiment, and weight is an "intruder" in the experiment, *only* weight is typically said to be the *confounding variable* or *confounder.*

(g) Weight of mice is confounded with temperature because it, in combination with temperature, influences the ROC of mice and, more than this, the design of the experiment is such that it is impossible to tell how much of the influence is due to the weight of mouse, how much of the influence is due to the temperature and how much is due to both on the ROC of mice. Weight of mice is *not* confounded with temperature *if* (circle none, one or more)

i. weight of mouse alone (without temperature) influences the ROC of mice.
ii. temperature alone (without weight of mouse) influences the ROC of mice.
iii. weight of mouse, in combination with a variable other than temperature, influences the ROC of mice.
iv. temperature, in combination with a variable other than weight of mice, influences the ROC of mice.
v. weight of mouse, in combination with temperature, influences the ROC of mice but it is not know what the contribution of either variable is in this influence.

(h) **True** / **False** Weight of mouse, not temperature, is considered to be the confounder (the "intruder") because we are interested in determining how temperature, not weight of mice, influences the ROC of mice. *If*, however, we had been interested in determining how weight of mouse, not temperature, influenced the ROC of mice, then temperature would have been the confounder. Sometimes, as we discover below, both variables can be considered to be equally important and so although they could be confounded with one another, neither one would be considered a confounder.

(i) **True** / **False** In this example, we are simply interested in *eliminating* the weight of mouse (confounder) influence on the response variable, to be able to clarify the influence of the temperature (treatment) alone on the response variable. If both variables, equally important, are confounded with one another, then we might be interested in determining in exactly what way ("additive", "multiplicative", "nonlinear") they are confounded with one another.

(j) Confounders are a (circle one) **problem** / **benefit** of the experiment.

(k) **True** / **False** Weight of mice is the (one and) *only* possible confounder in this experiment. (Hint: Do you think temperature could be confounded with the gender of the mouse?)

(l) Mouse gender is another possible confounder with temperature if, for example, it is observed that female mice have a lower ROC than male mice and, more than this, all cooler temperatures are (stupidly) assigned to female mice and all hotter temperatures are assigned to male mice in the experiment. As a consequence, (circle one)

i. it is clear that only temperature
ii. it is clear that only the gender of mice
iii. it is not clear whether the gender of mice or temperature or some combination of the two

influences the response variable, ROC of deer mice.

(m) Other possible confounders include (circle none, one or more):
health of mice / **age of mice** / **gender of lab technician**.

(n) **True** / **False** All variables not considered in the experiment *must* be confounders. (Hint: Decide whether or not the variables, "height of technician" carrying out the experiment or "gender of the administrator" in charge of the lab running the experiment, say, influence this experiment.)

(o) **True** / **False** *All* variables which are confounders are *known* to the experimenter.

2. *More Confounding: Music Types (artist, loudness), Breathing Rate and Heart Rate.* The effect of loudness and different musical artists on the heart rate of robins, chosen at random, is investigated.

	loudness →	soft	medium	loud
artist	Natalie Merchant	7.2, 8.1	8.4, 8.2	8.9, 9.2
	Matchbox Twenty	9.1, 8.7	9.2, 9.5	10.2, 12.7
	Handel	3.2, 4.1	4.3, 4.1	4.7, 4.5

Another variable, breathing rate, which is thought to influence the heart rates of robins, is not investigated in this study.

(a) Consider the following table.

	loudness →	soft	medium	loud
artist	Natalie Merchant	treatment 1	treatment 2	treatment 3
	Matchbox Twenty	treatment 4	treatment 5	treatment 6
	Handel	treatment 7	treatment 8	treatment 9

To say that a robin has been assigned treatment 1 means this robin has listened to (circle one)

i. a Natalie Merchant song played softly.
ii. a Matchbox Twenty song played loud.
iii. a Matchbox Twenty song played at medium volume.

(b) It is discovered later, after the experiment is complete, that, *un*intentionally, all low breathing rate robins are subjected to treatments 1,2 and 3, all medium breathing rate robins are subjected to 4, 5 and 6 and all high breathing rate robins are subjected to 7, 8 and 9. In this case, (circle one)

i. breathing rate is confounded with heart rate
ii. breathing rate is confounded with artist
iii. breathing rate is confounded with volume

(c) It is discovered later, after the experiment is complete, that, *un*intentionally, all low breathing rate robins are subjected to treatments 1,4 and 7, all medium breathing rate robins are subjected to 2, 5 and 8 and all high breathing rate robins are subjected to 3, 6 and 9. In this case, (circle one)

i. breathing rate is confounded with heart rate
ii. breathing rate is confounded with artist
iii. breathing rate is confounded with volume

(d) To reduce the influence of the breathing rate confounder, (circle one)

i. breathing rate should be assigned to the robins at random.
ii. volume should be assigned to the robins at random.
iii. artist should be assigned to the robins at random.
iv. volume and artist combinations (treatments) should be assigned to the robins at random.

(e) **True / False** The random assignment of treatments to robins also prevents other possible confounders such as music preferences from influencing the heart rate of individual robins.

(f) The random assignment of treatments to robins (circle one) **does / does not** prevent us to identifying how much of the influence on heart rate is due to the artist alone, how much is due to the volume alone and how much is due to artist and volume together[1].

3. *Dealing With Confounding Variables in Experiments: Randomization; Air Temperature, Mice Weight and Rate of Oxygen Consumption.* Four different mice are subjected to four different temperature levels to determine the effect of air temperature on the rate of oxygen consumption (ROC) of deer mice.

temperature	0^o F	10^o F	20^o F	30^o F
average ROC	7	9	12	16

   (a) Weight of mice is *confounded* with temperature if, for example, the temperatures are assigned to the four mice, numbered 1, 2, 3 and 4, in the following way.

table A	assign temperature	0^o F	10^o F	20^o F	30^o F
	to mouse	1	2	3	4
	which has weight	light	low–middle	high–middle	heavy

   That is, the coolest temperature, 0^o F, is assigned to the lightest mouse, numbered 1 and the hottest temperature, 30^o F, is assigned to the heaviest mouse, numbered (circle one) **2 / 3 / 4**

   (b) Relative to table A above, weight of mouse (circle one) **is as / is less** confounded with temperature if,

table B	assign temperature	10^o F	20^o F	30^o F	40^o F
	to mouse	1	4	3	2
	which has weight	light	heavy	high–middle	low–middle

   (c) **True / False** Table B is the better way, than table A, to assign temperature to mice, to reduce (disentangle) the confounding influence of weight of mouse (confounder) on the temperature (treatment), because it makes the assignment in the most *random* (mixed up) way, of the two assignment tables. In this case, randomization refers to the random assignment of temperature (treatment) to mice (experimental units) and is used to reduce the influence of the weight of mouse (confounder) on the ROC of mice (response variable).

   (d) **True / False** What if the mice were already mixed up? On the one hand, it might not seem necessary to assign the various temperatures at random to the mice because, for example, cooler temperatures would not be assigned to lighter mice and hotter temperatures would not be assigned to heavier

[1]This is also beyond the scope of the course.

mice. On the other hand, *cannot hurt to do random assignment* and it is very possible randomization may prevent other *unknown* confounders from influencing the response variable.

(e) **True** / **False** Assigning temperatures (treatments) to mice (experimental units) at random will always eliminate all confounders.

4. *Randomization, Using The TI–83: Mice, Temperatures and ROC.* Four different mice are subjected to four different temperature levels to determine the effect of air temperature on the rate of oxygen consumption (ROC) of deer mice.

temperature	0^o F	10^o F	20^o F	30^o F
ROC	4.5	7.8	9.7	12.2

(a) Using the TI–83[2], seed 7, to choose four different single–digits between one (1) and four (4), the temperatures (treatments) are assigned to the four mice, numbered 1, 2, 3 and 4, in the following random way.

table A	assign temperature	0^o F	10^o F	20^o F	30^o F
	(treatment)	1	2	3	4
	to mouse	1	4	3	2

That is, the coolest temperature, 0^o F (treatment 1), is assigned to the mouse numbered (circle one) **1** / **3** / **4**

(b) Using the TI–83[3], seed 12, to choose four different single–digits between one (1) and four (4), the temperatures (treatments) are assigned to the four mice, numbered 1, 2, 3 and 4, in the following random way. Fill in the blanks.

table B	assign temperature	0^o F	10^o F	20^o F	30^o F
	(treatment)	1	2	3	4
	to mouse	______	______	______	______

(c) The purpose of assigning temperatures to mice at random is to (circle one)

i. make the experiment unnecessarily complicated

ii. reduce or eliminate confounders

5. *Randomization, Using The Random Numbers Table: Clay Ingredient, Kiln Location (Heat) and Proportion of Cracked Clay Tiles.* Clay tiles are fired in a kiln. *Each clay tile is molded in one of three machines.* A manufacturer of clay roofing would like to investigate the effect of clay type on the proportion of

[2]7 STO→ MATH PRB Rand, then, immediately, MATH PRB randInt(1,4,10) ENTER.

[3]12 STO→ MATH PRB Rand, then, immediately, MATH PRB randInt(1,4,10) ENTER. Skip any repeated digits; in other words, to not use the same digit twice.

cracked tiles. Two different types of clay are to be considered; both clay types are identical, aside from the addition of ingredient A for clay type A and the addition of ingredient B for clay type B. The following design is used for this experiment.

	moulding machine	1	2	3
clay types	A	treatment 1	treatment 2	treatment 3
	B	treatment 4	treatment 5	treatment 6

(a) To say that a plate of 100 tiles has been assigned treatment one (1) means these tiles been (circle one)

i. made with ingredient A and molded by machine 1
ii. made with ingredient B and molded by machine 2
iii. made with ingredient A and molded by machine 2
iv. made with ingredient B and molded by machine 3

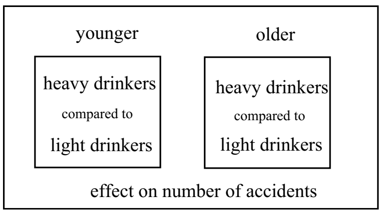
(b) Using the TI–83[4], seed 12, to choose four different single–digits between one (1) and six (6), the treatments are assigned to six plates of clay, numbered 1, 2, 3, 4, 5 and 6 in the following random way.

assign treatment	1	2	3	4	5	6
to plate of clay	______	______	______	______	______	______

7.3 Tools For Developing Experimental Designs

Exercise 7.3 (Observed Studies, Confounding and Blocking)

1. *Observed Study and Blocking For Confounding Variables: Alcohol Effect On Traffic Accidents With Age Confounder.* Indiana police records from 1999–2001 are analyzed to determine if there is an association between drinking and traffic accidents.



alchol vs accidents,
controlling for age confounder

[4]12 STO→ MATH PRB Rand, then, immediately, MATH PRB randInt(1,6,10) ENTER.

Figure 7.1 (Observed Study and Controlling For Confounding Variable)

(a) This is an observed study because (circle one)
   i. the police decided who was going to drink and drive and who was not.
   ii. the drivers decided who was going to drink and drive and who was not.
   iii. drivers were assigned to drink and drive or be sober drivers at random.

(b) Suppose age influences the number of traffic accidents. Age would be considered a confounding variable with drinking in the number of traffic accidents of Indiana drivers if (circle one)
   i. young drivers had a greater number of traffic accidents than older drivers.
   ii. intoxicated drivers had a greater number of traffic accidents than sober drivers.
   iii. it was not clear at the end of the study whether the number of traffic accidents was a consequence of being intoxicated or not, or whether it was a consequence of age.
   iv. it was not clear at the end of the study whether the number of traffic accidents was a consequence of being intoxicated or not, or whether it was a consequence of *gender*.

(c) One way to eliminate the confounding effect of age with drinking on the number of traffic accidents (to *block* (or control) for age) in this observed study would be to (circle one)
   i. assign drivers to be either drunk or sober at random (Is this possible, since the data was collected from police records?)
   ii. compare the number of traffic accidents of drunk drivers with sober driver who both have similar ages
   iii. compare the number of traffic accidents of drunk drivers with sober driver who both have different ages

2. *Another Observed Study and Controlling For Confounding Variables: Internet Effect On Learning With Average GPA Confounder.* A recent study was conducted to compare the academic achievement (measured by final examination scores) of Internet students with classroom students. Internet students did not attend class, but received all instruction over the Internet, whereas classroom students received instruction at a fixed time every week in a specified classroom.

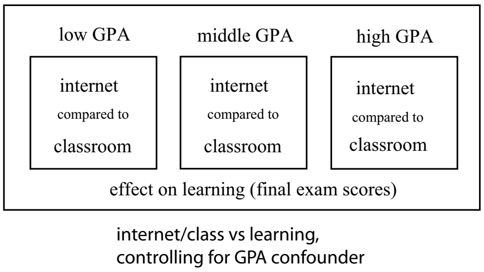


Figure 7.2 (Another Observed Study and Controlling For Confounding Variable)

(a) This is an observed study because (circle one)

i. the instructor decided who was a classroom student and who was an Internet student.

ii. the students decided to be either a classroom student or an Internet student.

iii. students were assigned to be “classroom” students and “Internet” students at random.

(b) Suppose average GPA influences academic achievement (measured by final examination scores). Average GPA would be considered a confounding variable with teaching method on the academic achievement of students if (circle one)

i. students with high average GPAs had better final examination scores than students with low average GPAs.

ii. Internet students had better final examination scores than classroom students.

iii. it was not clear at the end of the study whether students’ academic achievement was a consequence of being either an Internet students or classroom students, or was as a consequence of average GPA.

iv. it was not clear at the end of the study whether students’ academic achievement was a consequence of being either a male or female, or was as a consequence of average GPA.

(c) One way to eliminate the confounding effect of average GPA with teaching method on the academic achievement of students (to block for average GPA) in this observed study would be to (circle one)

i. assign students to be either “classroom” or “Internet” students at random (Is this possible, since these students choose between these two options themselves?)

ii. compare the academic achievement of classroom students with Internet students who both have similar average GPAs

iii. compare the academic achievement of classroom students with Internet students who both have different average GPAs

(d) **True** / **False** Controlling for the confounder average GPA in this study does not control for any other confounder. Each confounder must be controlled for separately from every other confounder in an observed study, unlike in a randomized design, where randomization takes care of all confounders all at once.

3. *Drug, Flu Symptoms, and Blocking For The Gender Confounder.* Consider the investigation of the effect of a new drug on reducing flu symptoms. In this observational study, one hundred and fifty patients receive the drug; 300 do not receive the drug. All patients were infected with the same strain of flu. A summary of the results of the experiment is given as follows. For example, 50 patients of the 150 who received the drug did not experience any reduction in flu symptoms.

flu symptoms →	reduced	not reduced	subtotals
drug	100	50	150
no drug	200	100	300
subtotals	300	150	450

(a) This is a study of (circle one)

i. the patients who had flu symptoms.

ii. the patients who received the drug.

iii. effectiveness of the drug on reducing flu symptoms.

iv. the patients who had flu symptoms and who received the drug.

(b) **True** / **False** *If* this study was a randomized experiment, all patients would first have to be infected with a mild strain of flu and then some would be selected to receive the drug (and, so, some would not), at random. This would most likely mean that around *half* of all the patients in the experiment would receive the drug (and, so, half would not receive the drug), which is not the case above. Consequently, this is *probably* an observed study.

(c) Of the patients who took the drug, the proportion of patients who had reduced flu symptoms,
$\frac{100}{150}$ = (choose one) $\mathbf{\frac{1}{3}}$ / $\mathbf{\frac{2}{3}}$ / $\mathbf{\frac{3}{3}}$

(d) Of the patients who did *not* take the drug, the proportion of patients who had reduced flu symptoms,
$\frac{200}{300}$ = (choose one) $\mathbf{\frac{1}{3}}$ / $\mathbf{\frac{2}{3}}$ / $\mathbf{\frac{3}{3}}$

(e) It would appear from this experiment that the drug (circle one) **does** / **does not** have any effect on reducing flu symptoms because the *same* proportion ($\frac{2}{3}$'s) of people experienced reduced flu symptoms whether they had taken the drug or not. In other words, this experiment appears to show that there is no association between drug and reduction in flu symptoms.

(f) It (circle one) **is** / **is not** clear from the table above how many males or females were involved in this study. Assume both males and females were involved in this study. Consequently, the *combined* (both male and female) number of patients who both received the drug and had reduced flu symptoms is (circle one) **20** / **80** / **100**.

(g) The doctors suspect gender is confounding the results. Consequently, *to block for gender*, they tabulate the effect of the drug on males and, separate from this, tabulate the effect of the drug on females, as shown below. For example, of 120 *males* who received the drug, 80 had reduced flu symptoms; whereas, of 30 *females* who received the drug, 20 had reduced flu symptoms.

male	reduced	not reduced	subtotals
drug	80	40	120
no drug	100	80	180
subtotals	180	120	300

female	reduced	not reduced	subtotals
drug	20	10	30
no drug	100	20	120
subtotals	120	30	150

The number of *male* patients who both received the drug and had reduced flu symptoms is (circle one) **20** / **80** / **100**.

(h) The number of *female* patients who both received the drug and had reduced flu symptoms is (circle one) **20** / **80** / **100**.

(i) The *combined* (both male and female) number of patients who both received the drug and had reduced flu symptoms, from the combined table above, is (circle one) **equal to** / **not equal to** the *sum* of the *female* patients who both received the drug and had reduced flu symptoms *plus* the *male* patients who both received the drug and had reduced flu symptoms.

(j) Of the *male* patients who took the drug, the proportion who had reduced flu symptoms is
$\frac{80}{120}$ = (choose one) **0.56** / **0.67** / **0.77**

(k) Of the *male* patients who did *not* take the drug, the proportion who had reduced flu symptoms is
$\frac{100}{180}$ = (choose one) **0.56** / **0.67** / **0.77**

(l) It would appear from this study that *males* (circle one) **should** / **should not** take the drug because a greater proportion of males experienced reduced flu symptoms who had taken the drug ($\frac{80}{120}$) than who had not taken the drug ($\frac{100}{180}$).

(m) Of the *female* patients who took the drug, the proportion who had reduced flu symptoms is
$\frac{20}{30}$ = (choose one) **0.56** / **0.67** / **0.77**

(n) Of the *female* patients who did *not* take the drug, the proportion who had reduced flu symptoms is
$\frac{100}{120}$ = (choose one) **0.56** / **0.67** / **0.83**

(o) It would appear from this study that *females* (circle one) **should** / **should not** take the drug because a lesser proportion of females experienced reduced flu symptoms who had taken the drug ($\frac{20}{30}$) than who had not taken the drug ($\frac{100}{120}$).

(p) **True** / **False** Although the combined study demonstrates there is *no* association between drug and reduced flu symptoms, there is a positive association between drug and reduced flu symptoms for the males, whereas there is a negative association between drug and reduced flu symptoms for females. This is an example of *Simpsons Paradox*. In this case, gender is confounded with the effect of the drug on flu symptoms.

(q) **True** / **False** It is (remotely) possible by chance alone that this data arise as the consequence of a randomized experiment and so it is possible that Simpson's Paradox occur in randomized experiments in addition to observational studies.

7.4 Statistical Models and Experimental Design

Not covered.

7.5 Determining Sample Sizes

Not covered.